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Book review

R. Dechter, Constraint Processing, Morgan Kaufmann, 2003.

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Constraint satisfaction is a relatively young research area of Artificial Intelligence addressing combinatorial optimization problems. Until recent years, there were only a few books describing the topic so it was not easy for newcomers to get in and to understand the techniques behind constraint satisfaction. This situation hindered education in the area so the community did not grow and develop as much as it could. It also led and still leads to many misunderstandings about constraint satisfaction techniques; the most embarrassing one is putting equality between constraint satisfaction and simple enumeration.

The book Constraint Processing by Rina Dechter with contributions from David Cohen, Peter Jeavons, and Francesca Rossi is a welcome introduction to the field of constraint satisfaction that will help researchers, educators, and students understand what constraint processing is about. It is a comprehensive book that can be used as a companion for courses on constraint satisfaction especially because the reader does not need to be an expert in the area to understand the text. The introductory character of the book makes it easy to read; nevertheless advanced students and researchers may also find deeper information on some topics there. Rina Dechter is an excellent researcher with contributions in many areas of constraint satisfaction and this is reflected in the book in both good and bad sense.

Let us now go through the contents of the book in more detail. The main text is split into basic and advanced parts; navigation through the contents is simplified by a chapter flow diagram. A very nice feature is a unified structure of all chapters. After the main text in a chapter there is always a summary, bibliographical notes, and exercises. That is great for those that want to scan briefly the contents of the chapter before deciding to read it or that want to continue in deeper studies of the topic. Exercises will surely be welcomed by teachers.

Chapter 1 is a standard book introduction describing the basic concepts of constraint satisfaction including some examples and giving mathematical background necessary for reading of the text. The basics of sets, graphs, and complexity theory are explained there

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but it is a bit surprising to me that the background does not cover logic, especially because later chapters contain material on SAT. Also, the very first reference in the book (Huffman and Cloves, 1975 on page 7) is not included in the bibliography.

Chapter 2 describes the basic concepts behind constraint satisfaction. Formal presentation of constraint networks is provided there together with examples of constraint models for some problems like n-queens, the crossword puzzle, or scene labeling. The focus is on formal properties of binary constraint networks but I miss a bit a description of how to convert a non-binary network (with non-binary constraints) to an equivalent binary one.

Chapter 3 is devoted to constraint propagation techniques so it is a very important part of the book showing that constraint processing is much more than simple enumeration. It introduces the notions of arc, path, and i-consistency and describes the basic algorithms (AC-1, AC-3, AC-4, PC-1, PC-2) to achieve these levels of consistency. Unfortunately, some details concerning AC-3, AC-4, and PC-2 algorithms are left unexplained (initialization and deletion of values in AC-4, updating a queue in AC-3 and PC-2) which complicates understanding of their non-trivial features. Actually, I think that AC-4 cannot be implemented using information only from this book and the interested reader must go to the original papers. The reference to PC-4 on page 66 is incorrect, it goes to the paper by Mohr and Henderson (1986), but actually their algorithm called PC-3 is not sound and PC-4 was proposed by Han and Lee (1988) as a correction of PC-3. In my opinion this chapter should be written more carefully especially because the presented techniques are very important for constraint satisfaction.

Chapter 4 describes directional consistency techniques including adaptive consistencies and bucket elimination. I have not seen these techniques to be used by existing constraints solvers and to be widespread. It is important to know about these techniques but it is a bit surprising to me that the length of this chapter is similar to the length of the previous chapter which indicates similar importance. Some techniques, like bucket elimination, are described even in more detail than, in my opinion, more important techniques from Chapter 3.

While I complained a bit about Chapters 3 and 4, I must offer applause for Chapters 5 and 6 that I really liked. Chapter 5 describes search strategies with look-ahead techniques, namely forward checking and partial and full look-ahead. Dynamic variable ordering is also discussed. Chapter 6 describes search strategies with look-back techniques, namely various versions of backjumping are presented. I just do not understand why look-back techniques are presented after historically newer look-ahead techniques. Moreover, backmarking included among look-ahead techniques is, in my opinion, a typical look-back technique (the name—backmarking—also indicates this). Last but not least, it would be nice to include some novel search techniques, like discrepancy search, that are used in practice more widely than some of the presented search algorithms.

Chapter 7, which closes the basic part of the book, briefly describes greedy local search techniques for constraint satisfaction. In particular, hill climbing (presented as stochastic local search), random walk, tabu search, and simulated annealing techniques are described. Combination with constraint propagation is also discussed there.

The advanced part of the book starts with Chapter 8 about advanced consistency techniques like relational consistencies and convex relations. The concepts are described in enough detail and they are clearly presented. Thought theoretically interesting, I have not seen these techniques in current constraint solvers, which again raises a question of their practical applicability.

Chapter 9 is devoted to tree decomposition techniques going in the direction of using a topological characterization of the problem to improve solving techniques and to identify tractable problems. Adaptive consistencies based on ideas presented in this section could be a way how to automatically improve efficiency of current constraint solvers, but still these techniques stay more on a theoretical level rather than being practically applied.

Chapter 10 is about combining search and inference, that is, about designing hybrid algorithms. The level of hybridization is driven by structural properties of constraint networks like the induced width and the size of cycle-cutsets. The chapter is clearly motivated and the case study (combinatorial circuits) makes the presented techniques practically interesting.

Chapter 11 continues the discussions from previous chapters, namely it is about tractable problems. This chapter is a contribution by David Cohen and Peter Jeavons. I really liked how the chapter is written. It is very clear and open even to non-theoreticians. Basically, the chapter is about identifying tractable problems using information about types of constraints. It complements the previous chapters that focus more on structural properties of the constraint networks.

Chapter 12 discusses temporal constraint networks which are a particular type of a constraint satisfaction problem. Both qualitative and quantitative approaches to modeling time are described; several algorithms for solving simple temporal networks are presented.

Chapter 13 is about solving constraint optimization problems. Branch-and-bound and Russian Doll Search are presented there, but most space is devoted to details of bucket elimination algorithm for optimization problems. Soft constraints are also very briefly discussed there.

Chapter 14 introduces probability networks that are important to represent uncertainty. I do not see much relation to constraints, other than using bucket elimination for belief updating.

Chapter 15 is the last chapter of the book and it is a contribution by Francesca Rossi. This is probably the most practically oriented chapter of the book; it describes the constraint logic programming framework and shows some examples or "real" programs. Constraints can naturally by integrated into logic programming where they generalize unification. Hence it is very easy to switch from logic programming (or more precisely Prolog) to constraint logic programming. The chapter is very clearly written and easy to understand. It looks like the chapter can stand alone because its reading is independent of the rest of the book. This chapter is a very nice conclusion of the generally well-written book.

Let me now summarize my personal view of the book. My first impression was very good and I can easily recommend the book as a nice introduction to the field. My recommended sequence of chapters for a one-semester course would be 2, 3, 4 (but less deep), 6, 5, 13, 15, 7, 9, 11. However, in my opinion the teacher that wants to give a course based on this book should already be quite familiar with constraint satisfaction. The reason is that it is not clear from the book which techniques are really used in practice (and hence important) and which techniques are rather theoretical. Actually, I think that the focus of some chapters is shifted apart from the mainstream. As I already mentioned, the book reflects Rina Dechter's research interests in both good and bad sense. If you want to know about the areas where she had some contributions, you will love the book. These results are deeply and clearly summarized in the book with references to further reading. However, I think that Dechter put too much preference on these areas while underestimating the role of other areas that are, in my opinion, more significant for understanding and applying constraint satisfaction technology. For newcomers, this may distort the view of the field so in this sense the book can be a little dangerous for the CP community. Let me be more specific. As far as I know most constraint solvers and real-life applications are built around generalized arc consistency and global constraints but much more space in the book is devoted to directional consistency and other consistency techniques that are not so widespread. There is almost nothing about global constraints and only simple arc consistency algorithms are covered by the book. I think that understanding AC-4 and AC-6 or even AC-2001/AC-3.1 is more important than knowing the details of consistency algorithms like directional i-consistencies or adaptive consistencies. I do not understand why chapters on temporal constraint networks (12) and probabilistic networks (14) are included in the book while at the same time there is nothing about other application areas, constraint modeling, dynamic problems, and constraint solvers. Moreover, the readers are left with the illusion that they must implement all these techniques from scratch if they want to apply constraint satisfaction technology to particular problems. Only Chapter 15 mentioned some constraint solvers in the area of CLP. I also did not find it very convenient to mix description of soft constraints with the description of optimization in Chapter 13. Despite similar solving techniques, I see these areas used for different purposes. People doing optimization, like minimization of makespan in scheduling, do not need to know about soft constraints. On the other hand, there are many different frameworks for description of soft constraints, like constraint hierarchies, valued constraint satisfaction or semiring-based constraint satisfaction, and these frameworks focus on different aspects like modeling preferences, uncertainty, probability etc. It is a pity that the reader is not well informed about these fields that are, in my opinion, very relevant to solving practical problems.

Despite my above criticism of the structure and contents, the book is definitely worth reading. It is an interesting introduction to the field that is nicely and clearly written and hence it is easy to read and understand. Sometimes the focus is shifted to Rina Dechter's own results, which is my only complaint about the book, but all fundamental areas of constraint satisfaction are covered. The reader will find there descriptions of all major algorithms used in constraint satisfaction together with explanation and comparison of their features and analysis of their complexity. It is also important to say that all the algorithms are presented in a uniform way which simplifies a lot their understanding. I strongly recommend reading this book to everyone who wants to know what is behind constraint satisfaction technology and I think that this book should definitely be in the bookshelf of everyone who teaches constraint satisfaction.